A novel bulk-gas-to-atomized-liquid reactor for enhanced mass transfer efficiency and its application to syngas fermentation

Syngas fermentation for fuels and chemicals is limited by the low rate of gas-to-liquid mass transfer. In this work, a unique bulk-gas-to-atomized-liquid (BGAL) contactor was developed to enhance mass transfer. In the BGAL system, liquid is atomized into discrete droplets, which significantly increases the interface between the liquid and bulk gas. Using oxygen as a model gas, the BGAL contactor achieved an oxygen transfer rate (OTR) of 569 mg·L⁻¹·min⁻¹ and a mass transfer coefficient (KLa) of 2.28 sec⁻¹, which are values as much as 100-fold greater than achieved in other kinds of reactors. The BGAL contactor was then combined with a packed bed to implement syngas fermentation, with packing material supporting a biofilm upon which gas saturated liquid is dispersed. This combination avoids dispersing these gas-saturated droplets into the bulk liquid, which would significantly dilute the dissolved gas concentration. Although this combination reduced overall KLa to 0.45–1.0 sec⁻¹, it is still nearly 20 times higher than achieved in a stirred tank reactor. The BGAL contactor/packed bed bioreactor was also more energy efficient in transferring gas to the liquid phase, requiring 8.63–26.32 J·mg⁻¹·O₂ dissolved, which is as much as four-fold reduction in energy requirement compared to a stirred tank reactor. Fermentation of syngas to ethanol was evaluated in the BGAL contactor/packed bed bioreactor using Clostridium carboxidivorans P7. Ethanol productivity reached 746 mg·L⁻¹·h⁻¹ with an ethanol/acetic acid molar ratio of 7.6. The ethanol productivity was two-fold higher than the highest level previously reported. The exceptional capability of BGAL contactor to enhance mass transfer in these experiments suggests its utility in syngas fermentation as well as other gas-liquid contacting processes.